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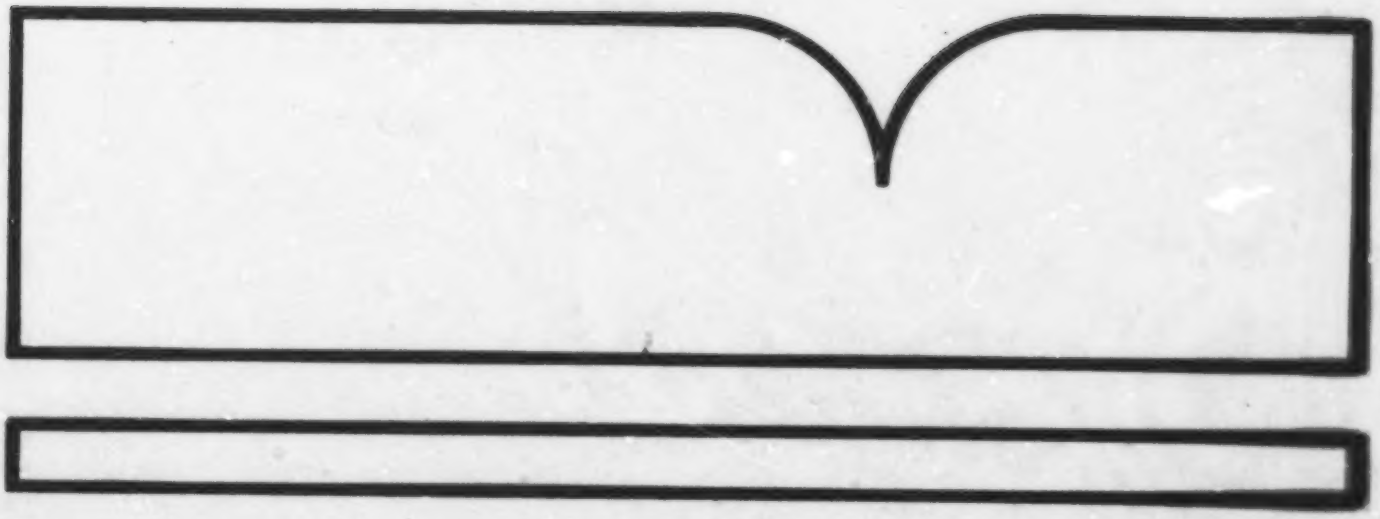

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16. ABSTRACT

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Avoidance Responses of Salmon and Trout to Air-Supersaturated Water

DONALD G. STEVENS, ALAN V. NEBEKER, AND ROCKY J. BAKER

United States Environmental Protection Agency, Western Fish Toxicology Station
1350 Southeast Goodnight Avenue, Corvallis, Oregon 97330

Abstract

Coho (*Oncorhynchus kisutch*), sockeye (*O. nerka*), and chinook (*O. tschawytscha*) salmon smolts, and rainbow trout (*Salmo gairdneri*) avoided air-supersaturated water when tested in a shallow round tank. Steelheads (*S. gairdneri*) did not consistently avoid the supersaturated water and died from gas bubble disease. The salmon and rainbow trout generally avoided 145 and 125% saturation but did not always avoid 115%. Territorial activity reduced avoidance by steelheads and rainbow trout.

The ability of certain species of fish to survive air-supersaturation of water may depend upon whether or not that fish can detect and avoid supersaturated water. Avoidance can be accomplished by either sounding or moving laterally away from the supersaturated water. Meekin and Turner (1974) reported that when given an alternative water source, chinook salmon (*Oncorhynchus tschawytscha*) showed a strong preference for equilibrated over supersaturated water. Blahm et al. (1976) tested juvenile chinook salmon and steelhead (*Salmo gairdneri*) in a divided trough having 130% N_2 on one side and 102% N_2 on the other side. Two groups of steelhead apparently did not avoid nitrogen supersaturation, as 50% died in 42.5 and 43 hours and all fish contracted gas bubble disease. However, no chinook salmon died during 192 hours exposure, and only 10% showed signs of gass bubble disease. No lateral avoidance was observed during these tests because of turbid water. Dawley et al. (1976) indicated that chinook salmon and steelheads may detect supersaturation and avoid it vertically by sounding in deep tanks. Gray and Haynes (1977) monitored adult chinook slamon in the Snake River with pressure-sensitive radio transmitters; fish migrating upstream in supersaturated water spent about 89% of their time below the critical supersaturation zone but swam at shallow depths during the following fall and spring migrations when the river was normally saturated.

The present studies conducted at the Western Fish Toxicology Station (WFTS) tested the lateral avoidance response of several fish species to various concentrations of supersaturated water.

Methods

All tests were done in unchlorinated well water aerated to near saturation under normal atmospheric pressure. The alkalinity and hardness were near 27 mg/liter (as $CaCO_3$) and the pH was 7.1 during the test period. Supersaturated water was produced and controlled by metered injection of compressed air into the water supply under pressure (Nebeker et al. 1976). Saturation levels were verified by five gas chromatograph determinations during the test period, and monitored by at least one Winkler dissolved oxygen determination during each individual test. Supersaturated water was delivered to a rectangular tank divided into four sections by glass partitions of decreasing height (Fig. 1). Excess gas was serially stripped from the water as it cascaded over the partitions. Water for the three test concentrations, 145%, 125%, and 115%, was taken from behind the partitions and the control water was supplied from a separate head tank.

The avoidance test tank (Fig. 1) was 183 cm in diameter and 92 cm deep. Water depth was maintained at 31 cm by a standpipe. The tank was divided into eight pie-shaped chambers by opaque Plexiglas panels 61 cm long and 36 cm high which left a central open area (61 cm in diameter) around the drain. The entrance into each chamber was 20 cm wide and the rear of the chamber consisted of a perforated Plexiglas panel which separated the chamber from the incoming water. This panel delivered an even

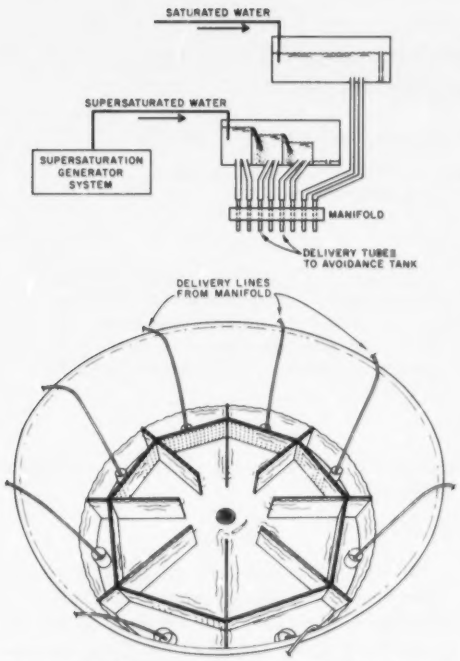

FIGURE 1.—*Diagrams of the delivery system for air-supersaturated water (upper panel) and of the test tank (lower panel) used in studies of salmonid avoidance of air-supersaturated water.*

flow of water into the test area. Water from a delivery manifold entered a standpipe at about 5 liters/minute and flowed through the perforated panel to the chamber. Dye tests indicated that the wedge-shaped plume of water leaving the chambers was maintained all the way to the center drain and was not significantly disrupted by fish activity.

The entire area above the tank was enclosed in black hardboard and plastic sheeting to prevent disturbance from room activity and lighting. Under the top of this tent were mounted a 16-mm motion picture camera and four fluorescent lights. The camera was activated by a motor-driven cam which exposed one frame every 2 minutes.

Fish used in the tests were reared from eggs provided by the Oregon Department of Fish and Wildlife. They included steelhead and coho salmon (*Oncorhynchus kisutch*) from the Alsea River, rainbow trout (*Salmo gairdneri*) and chinook salmon from the Willamette River, and sockeye salmon (*Oncorhynchus nerka*) from the Columbia River. All fish were parr-smolt size and their weight ranged from 30 to 45 g.

In each test 10 fish were placed in the tank for a minimum of 12 hours of acclimation in saturated water. The camera was started during the acclimation period and operated throughout the test period. Visual observations, without disturbing the fish, were also made to determine when avoidance behavior was established. When avoidance was observed, the various dissolved air concentrations were changed among chambers, generally by switching concentrations in opposite chambers. A continued avoidance response would be indicated by a decrease in the number of observations of fish in the higher concentrations (formerly lower concentrations) and a corresponding increase in observations of fish in the lower concentrations, an "observation" being the position of each fish in each film frame.

Water at each air concentration was piped into two adjacent chambers. The number of live fish recorded on the film in each pair of chambers was tabulated in hourly totals. Territorial activity was estimated by the number of frames that recorded sufficient disturbance of the water surface to distort the reflection of one of the fluorescent lamps. Fish that died were not counted or removed from the tank during the test period.

Differences between the hourly totals were subjected to analysis of variance to determine if there was a significant relationship between the changes in observations and the changes in concentration. The number of observations during the last hour before a concentration switch and those of the second hour after a change were used for the calculations. The differences between the number of observations 2 hours apart during the acclimation period provided the data for a zero-change in concentration. Data from the first hour of acclimation and the first hour after a change were not used, allowing the fish that time for adjustment.

Results and Discussion

The film record of the acclimation period indicated no preference of any species for any specific chamber or pair of chambers. Fish rarely were randomly distributed among chambers at the start of a test period, but this was a minor limitation for the experiments because it was

TABLE 1.—*Distribution of salmonid fish in three concentrations of air-supersaturated water and a control. All species except steelhead showed significantly different distributions among gas concentrations in one or more tests (analysis of variance* $P < 0.05$*).*

Fish	Test[b] number	Number of live fish	Test duration (hours)	Mean number of observations per hour at each gas concentration[a]				Percent mortality during test
				High (145 ± 4)[c]	Intermediate (125 ± 3)[c]	Low (115 ± 2)[c]	Control (98 ± 2)[c]	
Steelhead	1	10	14	37 (22)	44 (25)	47 (27)	44 (26)	90
Rainbow trout	1	10	44	24 (15)	32 (21)	45 (29)	54 (35)	80
	2	2	5	9 (13)	12 (18)	30 (48)	13 (21)	0
Coho salmon	1	10	8	57 (18)	71 (22)	72 (22)	121 (38)	0
	2	10	16	32 (10)	39 (12)	95 (29)	158 (49)	0
	3	10	4	27 (8)	55 (17)	59 (18)	184 (57)	0
Sockeye salmon	1	10	7	53 (16)	63 (19)	93 (29)	115 (36)	0
	2	10	4	63 (20)	65 (20)	98 (31)	95 (29)	0
	3	10	2	46 (15)	17 (5)	78 (24)	180 (56)	0
	4	10	2	62 (19)	40 (13)	100 (31)	120 (37)	0
Chinook salmon	1	10	8	67 (21)	68 (21)	72 (23)	109 (35)	0
	2	10	16	45 (15)	61 (21)	93 (31)	99 (33)	20
	3	8	4	41 (16)	62 (24)	64 (25)	88 (35)	0

[a] Number in parentheses is percent of total observations.
[b] Concentrations of air were switched to opposite chambers between successive tests of a species.
[c] Total-gas percent saturation (mean ± SD).

the changes in distribution that were monitored.

The steelheads and rainbow trout suffered greater mortality than the salmon tested (Table 1). The steelheads died sooner than the rainbow trout and did not demonstrate any significant avoidance behavior. During the acclimation period and early parts of the test period we saw considerable amounts of territorial activity by one or more steelheads, which caused constant fish movement and turmoil in the test tank. The continued loss of steelheads suggests either they were more sensitive to supersaturation than the other species, or the absence of an effective avoidance response due to territorial activity of some fish.

Mortality among rainbow trout occurred more slowly and the survivors eventually showed a positive avoidance response that was significant at the 0.05 level. The two surviving rainbow trout preferred the low gas concentration over the control level.

Coho salmon generally preferred control water during the first test. Following the first and second concentration switch the fish avoided the high concentration and again showed an increased preference for control water. None of the fish died during the tests and the results were significant at the 0.005 level.

The avoidance response of sockeye salmon to supersaturated water occurred more rapidly than in other species. In successive tests, their response times shortened considerably; the fish actively avoided the high and intermediate gas concentrations within 2 hours. The shortened response time may have resulted from the

schooling characteristics of sockeye salmon. The results were significant at the 0.005 level.

Chinook salmon did not show obvious avoidance of any concentration during the first test period. However, there was a general preference for control water. The next two tests indicated an avoidance of the high concentration. The results were significant at the 0.05 level.

Data to illustrate territorial activity were recorded from the last hour of acclimation and the first hour of the test period for each species. The percentage of frames showing considerable disturbance during these 2 hours for each species were steelheads 46%, rainbow trout 41%, coho salmon 14%, sockeye salmon 0%, and chinook salmon 6%.

These results indicate that juvenile rainbow trout and coho, sockeye, and chinook salmon can detect air-supersaturated water and that they will move laterally to avoid it. Our data support the findings of Meekin and Turner (1974) and Blahm et al. (1976) for chinook salmon. The lack of avoidance by steelheads is consistent with the research by Blahm et al. Our work does not address the possibility that steelheads and other species might sound vertically to avoid air-supersaturated water. It does show, however, that territorial activity by some fish may inhibit an escape from stressful conditions by others of their species.

References

Blahm, T. H., R. J. McConnell, and G. R. Snyder. 1976. Gas supersaturation research, National Marine Fisheries Service Prescott Facility—1971 to 1974. Pages 11–19 *in* D. H. Fickeisen and M. J. Schneider, editors. Gas bubble disease. CONF-741033, Technical Information Center, United States Energy Research Development Administration, Oak Ridge, Tennessee, USA.

Dawley, E., B. Monk, M. Schiewe, F. Ossiander, and W. Ebel. 1976. Salmonid bioassay of supersaturated dissolved air in water. EPA-600/3-76-056, United States Environmental Protection Agency, Duluth, Minnesota, USA.

Gray, R. H., and J. M. Haynes. 1977. Depth distribution of adult chinook salmon (*Oncorhynchus tshawytscha*) in relation to season and gas-supersaturated water. Transactions of the American Fisheries Society 106:617–620.

Meekin, T. K., and B. K. Turner. 1974. Tolerance of salmonid eggs, juveniles and squawfish to supersaturated nitrogen. Washington Department of Fisheries Technical Report 12:78–126.

Nebeker, A. V., D. G. Stevens, and J. R. Brett. 1976. Effects of gas supersaturated water on freshwater aquatic invertebrates. Pages 51–65 *in* D. H. Fickeisen and M. J. Schneider, editors. Gas bubble disease. CONF-741033, Technical Information Center, United States Energy Research Development Administration, Oak Ridge, Tennessee, USA.